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Interactive Operations for Understanding Embedded Sensor Domains

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1 Introduction

Embedded sensors have the potential to provide users vast amounts of information about the environment [Estrin et al. 2001]. However, in many situations, the sensors and associated databases are only capable of delivering low-level, unstructured data such as raw measurements. If users are to be able to extract meaning from the stream of data, interfaces must be provided to allow users to form and execute queries.

We implemented visualizations of the sensor domain and enabled a user to interactively plan and understand the sensor domain. We consider a military use of sensors: providing early warning of movement toward friendly positions [USMC Combat Development Command 1997]. The user views each sensor output on a dial-shaped or numerical display and integrates these values into a coherent picture to determine what action to take.

We consulted with domain experts to determine the operations and limitations with current interfaces to remote sensors. They noted the following driving issues. Current sensor suites require that line-of-sight contact be maintained (possibly through relays) to each sensor. It is hard to know what area is covered by the existing sensors. It is hard to predict how best to extend the current domain over which the sensors are effective.

2 Implemented Visualization Methods

We visualize the domain of sensors and line-of-sight relationships between sensors (top left). We add the sensor coverage in the domain (top right). The color indicates how many sensors extract the data for their reading from that region. (Key: red=1, yellow=2, green=3, blue=4.) The coverage computations account for the terrain shape, whereas the simple domains do not. Finally, we enable the user to plan sensor locations to most effectively monitor a space. Compare the bottom pair of images in the figure with the top pair. The bottom images show the result of the user interactively specifying a new string of sensors. Note how the sensor at the far left can be seen to have line-of-sight contact in only one direction with this interactive visualization.

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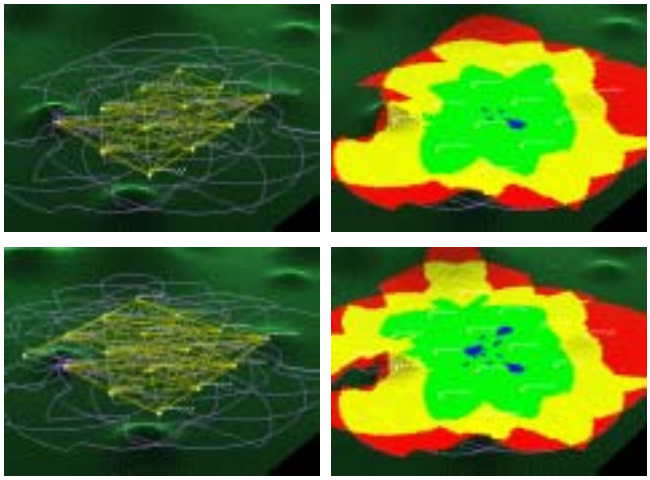

3 Discussion

Our initial efforts have focused on design of the sensor environment. The geometric operations may be grouped into area-based operations (extension of a domain and coverage within that domain) and point-based operations (line-of-sight queries). We would like to extend our efforts to include interactive detection of objects in the environment. This requires integration of our interface with a tracking algorithm [Schmidt et al. 2004].

We would like to be able to add different types of sensors. Thus far, we have largely been considering point-sampling sensors, such as magnetic or vibration detectors; however, imaging sensors are in use. The domain and coverage queries become more complex geometric problems, requiring the integration of qualitatively different shapes into a single geometric description.

This simple interface improves the understand of the sensor domain. The interactive 3D display for an application that had not previously seen such a display gives the user a tool for planning how to best use the resources available to get information. The interactions themselves require nothing more than simple desktop or mobile systems, but the 3D display converts important operations from challenging to interactive.

References

DEBORAH L. ESTRIN ET AL., Ed. 2001. *Embedded, Everywhere*. National Academy Press.

SCHMIDT, G. S., CHEN, S.-L., BRYDEN, A. N., LIVINGSTON, M. A., ROSENBLUM, L. J., AND OSBORN, B. R. 2004. Multidimensional visual representations for underwater environmental uncertainty. *IEEE Computer Graphics and Applications 24*, 5 (September/October), 56–65.

U.S. MARINE CORPS COMBAT DEVELOPMENT COMMAND, 1997. Remote sensor operations.